WiMAX System Level Modeling Methodology: A Tutorial

Raj Jain

Professor of Computer Science and Engineering
Washington University in Saint Louis
jain@wustl.edu
http://www.cse.wustl.edu/~jain

The slides are available on-line in AWG-AATG Methodology Documents folder in WiMAX Forum AATG Group Documents

WiMAX F2F Meeting, Hawaii
January 30, 2008

- Link-Level vs. System-Level Simulation
- System Modeling Parameters
- Application Traffic Models
- MAC Layer Modeling
- PHY Modeling
- Annexes
- 10 Facts About AATG Simulation Effort

Goals of System Level Model

- Provide quantitative proof of WiMAX superiority
- Carriers need:
  - Capacity Planning
  - Performance Optimization
  - Operational Guidelines
- Users need:
  - Operational Guidelines
- Vendors need:
  - Performance impact of various features

⇒ Develop a system level simulation methodology and simulation package for application performance analysis

- Consists of three related projects
  - System Level Simulation Methodology
  - Physical Layer Model Library
  - System-Level NS-2 Simulator

System-Level Simulation Methodology

- Agreed upon by WiMAX Forum members
- Can be used by anyone to develop their own simulation
- Can be used with any modeling platform: NS-2, OPNET, …
- Specifies parameter values: ranges and default
- Specifies features and methods
- Allows comparison of performance results from different vendors
- Will be used in the WiMAX Forum's NS-2 Model
- Similar documents exist for 3GPP/3GPP2

System Simulation Approach

- Simulate multiple WiMAX cells
- Simulate application traffic streams; use realistic traffic models
- Distribute user session randomly among the cells
- Utilize neighboring cell traffic to create interference in the center cell
- Abstract PHY to a table/graph mapping physical condition to Block Error Rate (BLER)

Ref: WiMAX System-Level Evaluation Methodology V2.0, December 12, 2007, http://www.wimaxforum.org/apps/org/workgroup/aatg/download.php/25704/WiMAX_System_Evaluation_Methodology_071215R2.pdf

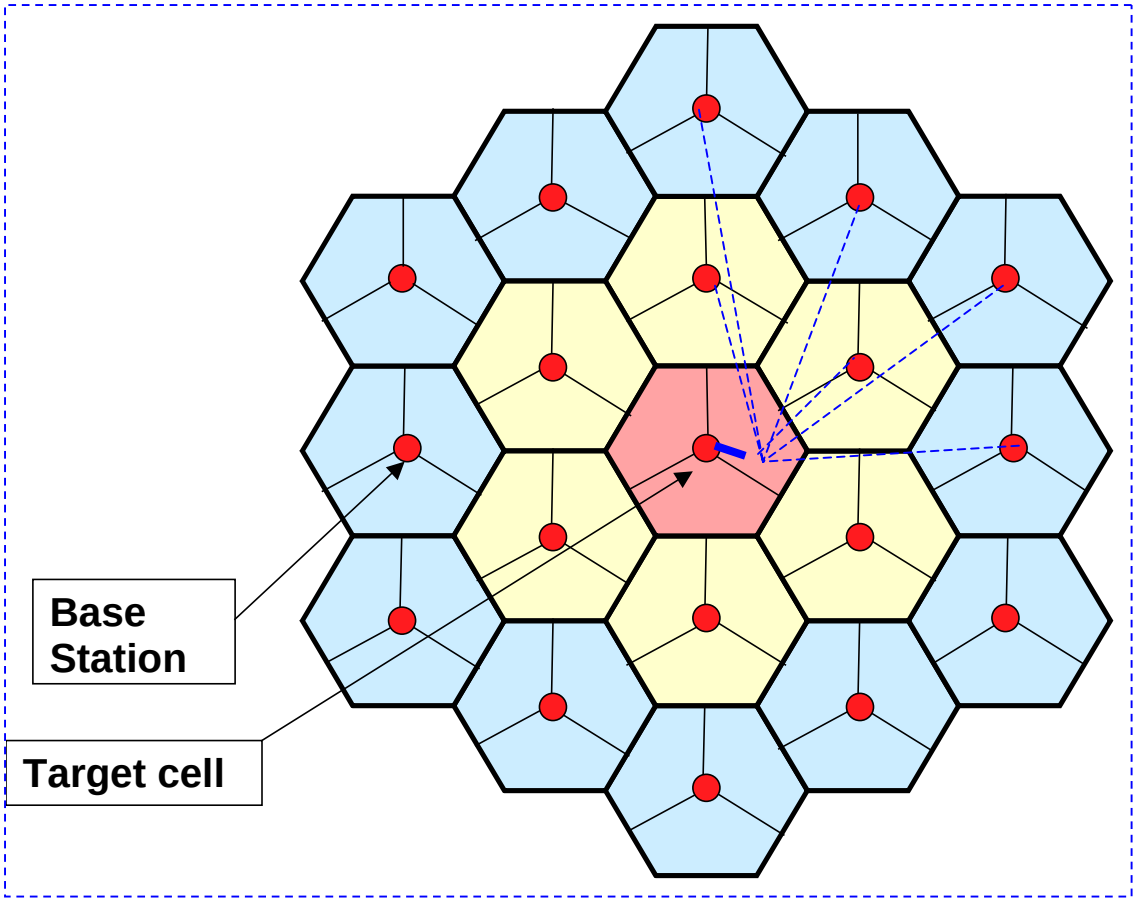
Components of System Level Model

- **System Definition**: Topography, Cell size, Height, Cell size, Customer density, …
- **Applications**: VOIP, VoD, Workload Characteristics, QoS Requirements
- **MAC Layer**: ARQ, Burst Allocation, Scheduling
- **PHY Model**: Channel models, MIMO, …, PHY abstraction

Organization of Methodology Document

- **System Definition**: Topography, Cell size, Height, Cell size, Customer density, … [Chapter 2]
- **Applications**: VOIP, VoD, Workload Characteristics, QoS Requirements [Chapter 3]
- **MAC Layer**: ARQ, Burst Allocation, Scheduling [Chapter 4]
- **PHY Model**: Channel models, MIMO, …, PHY abstraction [Chapter 5]

Topology for System Simulation



[3GPP]

Network Configuration Parameters

Parameter	Description	Value Range
N_c	Number of cells.	**19**
S	Number of sectors/cell.	1, **3**, 4, 6
$N_s = SN_c$	Total number of sectors.	19, **57**, 76, 114
R	BS-to-BS distance	0.5 to 30 km **(1 km)**
ϕ_{BS}	Orientation (boresight angle) of each sector as defined by 3GPP-3GPP2 [10]	$S = 3$: $\phi_{BS} = 30, 150, 270$ $S = 6$: $\phi_{BS} = 0, 60, 120, \ldots 300$
K	Number of frequency allocations in the network.	**1**, 2, 3, 4, 6
F_{BS}	Frequency allocation (integer index) used in each BS sector.	**1**, 2, 3, 4, 5, 6
	Operating Frequency	2.0–3.5 GHz (**2.5 GHz**)
	Duplexing Scheme	**TDD**

System Modeling Parameters

1. Network Configuration Parameters
2. Base Station Equipment Model Parameters
3. Subscriber Station Equipment Model Parameters
4. OFDMA Air Interface Parameters
5. Propagation Model Parameters
6. Methodology Parameters
7. Dynamic System Simulation Features
8. Fading and Mobility Channel Model
9. Parameters for system outage calculation

Key Contribution: These parameter values have been accepted as valid ranges and defaults by our PHY experts.

Application Classes

Class	Application	Bandwidth Guideline		Latency Guideline		Jitter Guideline	
1	Multiplayer Interactive Gaming	Low	50 kbps	Low	< 25 msec	N/A	
2	VoIP & Video Conference	Low	32-64 kbps	Low	< 160 msec	Low	<50 msec
3	Streaming Media	Low to High	5 kbps to 2 Mbps	N/A		Low	<100 msec
4	Web Browsing & Instant Messaging	Moderate	10 kbps to 2 Mbps	N/A		N/A	
5	Media Content Downloads	High	> 2 Mbps	N/A		N/A	

Application Traffic Models

- User-Level Traffic Models
  - Transactions
  - File transfers
  - Web pages
- IP Level Traffic Models
  - Packet size distribution
  - Inter-arrival time distribution

Quake 2 Traffic Model Parameters

Session Duration (hour)	Extreme (a=1, b=0.1), Truncated (0, 2)		
Client/Server	Data	Model	
Client to Server	Packet Inter-arrival time (msec)	Lower 4.5%, x<18:Extreme	a=6.57, b=0.517
		Upper 95.5%, x>= 18: Extreme	a=37.9, b=7.22
	Packet Sizes (byte)	Seven Distinct values	10.6%:36, 26.4%: 42, 6.26%: 44, 13.9%: 45, 4.95%: 46, 16.3%: 48, 21.5%: 51
Server to Client	Packet Inter-arrival time (sec)	Lower 4.8%, x<60:Extreme	a=58.2, b=7.47
		Upper 95.2%, x>= 60: Normal	a=100, b=17.7
	Packet Sizes (byte)	Lower 27.6%, x<55:Extreme	a=46.7, b=4.39
		Upper 72.4%, x>= 55: Extreme	a=79.7, b=11.3

Applications

3.1 INTERNET GAME TRAFFIC MODEL (CLASS 1)
3.2 VOIP TRAFFIC MODEL (CLASS 2)
3.2 VIDEO CONFERENCE TRAFFIC MODEL (CLASS 2)
3.3 PTT TRAFFIC MODEL (CLASS 2)
3.4 MUSIC/SPEECH TRAFFIC MODEL (CLASS 3)
3.5 VIDEO CLIP TRAFFIC MODEL (CLASS 3)
3.6 MOVIE STREAMING TRAFFIC MODEL (CLASS 3)
3.7 MBS TRAFFIC MODEL (CLASS 3)
3.8 IM TRAFFIC MODEL (CLASS 4)
3.9 WEB BROWSING (HTTP) TRAFFIC MODEL
3.10 EMAIL TRAFFIC MODEL (CLASS 4)
3.11 TELEMETRY TRAFFIC MODEL (CLASS 5)
3.12 FTP TRAFFIC MODEL (CLASS 5)
3.13 P2P TRAFFIC MODEL (CLASS 5)
3.14 VPN SERVICE
3.15 NRTV (NEAR REAL TIME VIDEO) TRAFFIC MODEL [3GPP]

Key Contribution: Many of these models are AATG original and are now part of 802.16m

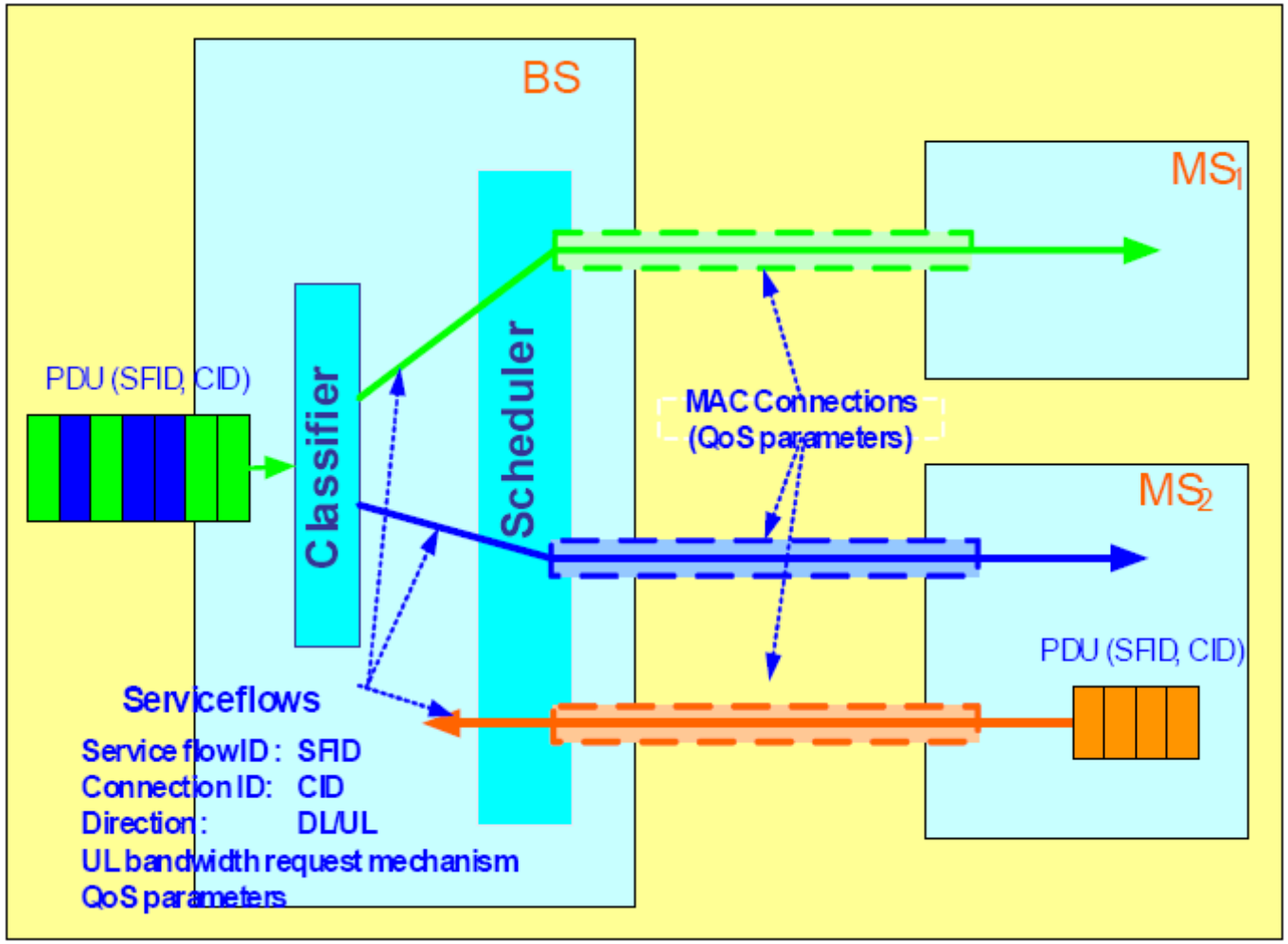
Performance Metrics

- Output Metrics for Infinite Buffer Models
  - Average Sector Throughput (kbps/Cell)
  - Average connection throughput
  - Block error rate
  - Residual Block Error Rate (after max ARQ/H-ARQ exhausted)
  - Average Block delay per sector
- Output Metrics for Real-Traffic Models
  - Transaction completion time
  - Transactions per second
  - Fairness among similar users
  - Probability of Transactions in Error

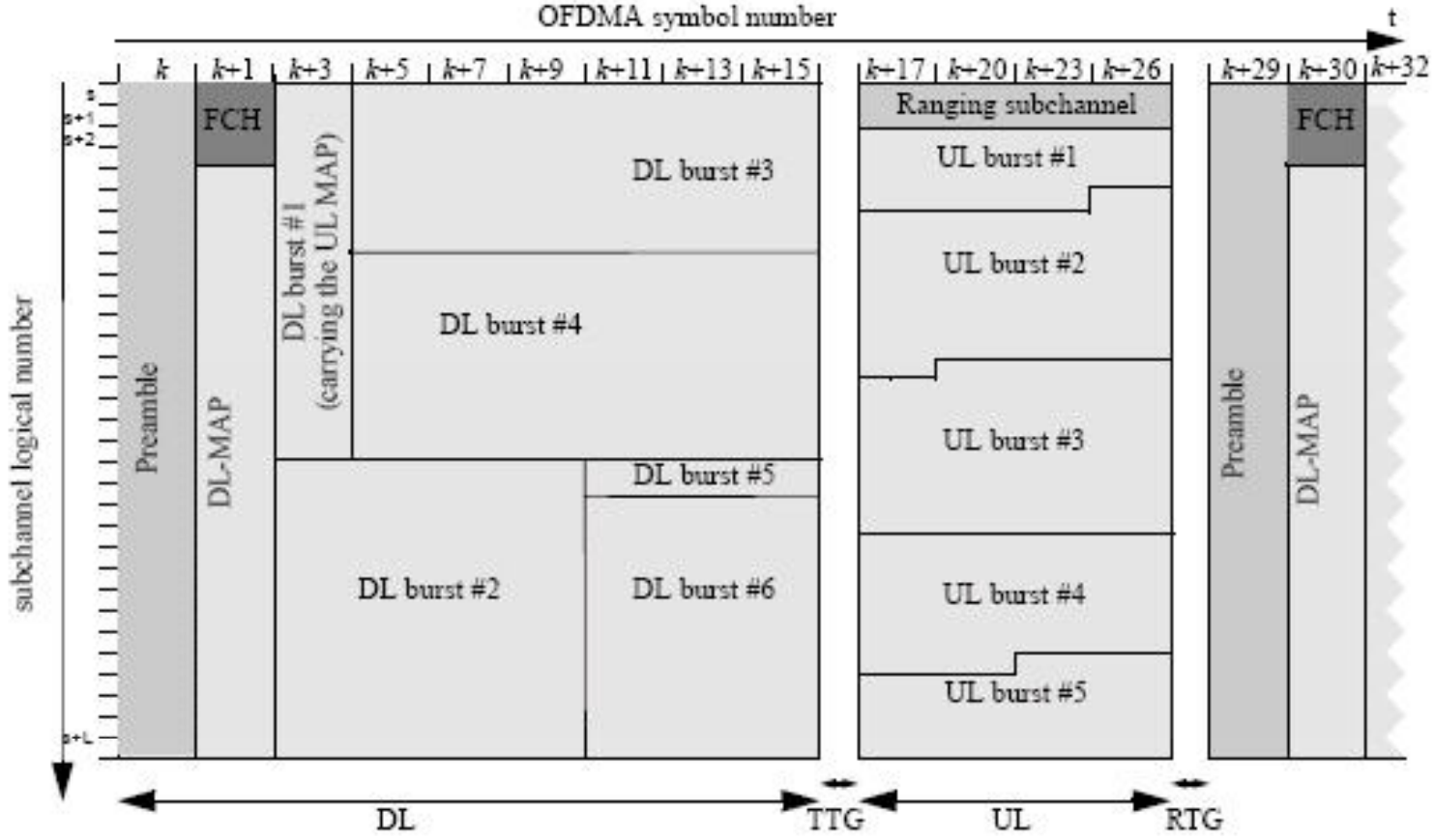
MAC Layer Modeling

4.1 CONVERGENCE SUBLAYER
4.2 MAC PDU FORMATS
4.3 ARQ MECHANISMS
4.4 MAC SUPPORT OF PHY LAYER
4.5 SERVICE FLOW OPERATION
4.6 MAC SCHEDULER
4.7 UL/DL MAPS
4.8 H-ARQ
4.9 MOBILITY MANAGEMENT
4.10 POWER MANAGEMENT - SLEEP-IDLE MODE
4.11 SECURITY (LATER RELEASE)
4.12 MBS (LATER RELEASE)
4.13 BUFFER MANAGEMENT

Scheduler Components



DL/UL MAPs



DL/UL MAP Information Elements

MAP	IE size (bits)
Fixed Compressed MAP (DL + UL + CRC)	N_1 (152)
Ranging region allocation IE (3IEs)	N_2 (168)
Fast feedback allocation IE	N_3 (52)
HARQ ACK region allocation IE	N_4 (36)
Fixed overhead in HARQ DL MAP IE	N_5 (68)
Fixed overhead in HARQ UL MAP IE	N_6 (44)
Interference and Noise IE	N_7 (24)
UL HARQ/user	N_8 (33)
DL HARQ/user	N_9 (44)
Additional Optional Fields	??

Note: This is offered as an example of MAP elements and their sizes. Additional IEs **may/will** be present in certain frames (depending on options implemented). WMF members are welcome to propose & agree on a baseline representation prior to simulator development. Above list offers a viable starting point.

PHY Modeling

5.1 PHY MODEM ABSTRACTION FOR SYSTEM SIMULATION

5.2 MODELLING ADVANCED PHY FEATURES

- 5.2.1 Advanced Antenna Systems
- 5.2.2 Transmit Diversity

5.3 CHANNEL MODELS FOR SYSTEM SIMULATION

- 5.3.1 Erceg Model
- 5.3.2 Other Channel Models

5.4 MIMO ABSTRACTION

- 5.4.1 General Per-Tone Model
- 5.4.2 SISO/MISO
- 5.4.3 Linear Receivers
- 5.4.4 2x2 Spatial Multiplexing (Vertical Encoding, Matrix B)
- 5.4.5 Qx1 Beamforming
- 5.4.6 Qx1 CDD (Cyclic Delay Diversity)
- 5.4.7 Impact of Receiver Impairments

Key Contribution: MIMO abstraction is an AATG original and components of it will be submitted to 802.16m

PHY Layer Modeling: Channel Models

Table 5.3.1: Mixed User Channel Model for Performance Simulation

Channel Model	Numberof Paths	Speed (km/h)	Fading	Assignment Probability
ITU Veh. B. Ch-103	6	3	Jakes	0.60
ITU Veh. A. Ch-104	6	30	Jakes	0.30
	6	120	Jakes	0.10

Table 5.3.2: Channel Models and associated assignment probability distribution

Channel Model	Multi-path Model	# of Paths	Speed (km/h)	Fading	Assignment Probability
Model 1	Ch-100	1	30	Jakes	0.1
Model 2	Ch-100	1	120	Jakes	0.1
Model 3	Ch-104	6	30	Jakes	0.1
Model 4	Ch-104	6	120	Jakes	0.1
Model 5	Ch-102	4	3	Jakes	0.3
Model 6	Ch-103	6	3	Jakes	0.3
Note: Fading model is Raleigh. The fading spectrum model is Jakes. Assignment probability is variable. The values in this table represent recommended defaults.					

Combining SINR

- SINR = Signal to Interference and Noise Ratio
- Channel Quality Indicator *C = fn(SINR)*
- **Problem**: Combine SINR for n subcarriers to a single SINR for the channel
  - $SINR_{eff} = f^{-1}\{1/n \sum f(SINR_k)\}$
- **Possible Solutions**: EESM, MIC, MIM, ECRM
- Exponential Effective SINR Mapping
  - Mapping Function: Exponential

$$F(SINR_k)=e^{-SINRk/\beta}$$

  - β is adjusted to match the environment
  - Effective SINR:

$$SINR_{eff} = -\beta \ln \{1/N \sum e^{-SINRk/\beta}\}$$

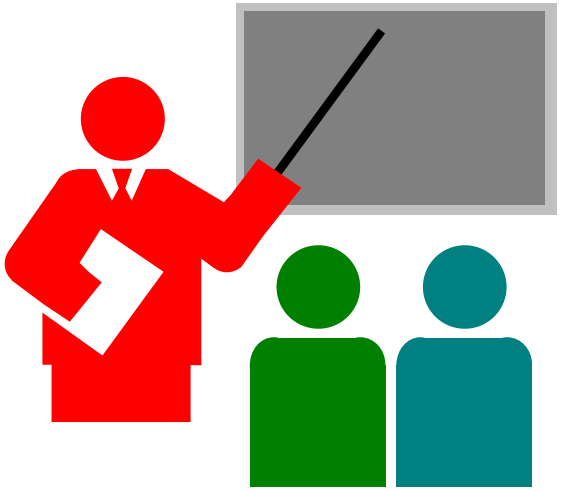
APPENDIX A: A TUTORIAL ON CHANNEL MODELS

- A.1 BASIC CONCEPTS
  - A.1.1 Channel
  - A.1.2 Path Loss
  - A.1.3 Shadowing
  - A.1.4 Multipath
  - A.1.5 Tapped Delay Line Model
  - A.1.6 Doppler Spread
- A.2 EMPIRICAL PATH LOSS MODELS
  - A.2.1 Hata Model
  - A.2.2 COST 231 Extension to Hata Model
  - A.2.3 COST 231-Walfish-Ikegami Model
  - A.2.4 Erceg Model
  - A.2.5 Stanford University Interim (SUI) Channel Models
  - A.2.6 ITU Path Loss Models

Other Annexes

- ANNEX B: EESM PHY ABSTRACTION
- ANNEX C: MIC PHY ABSTRACTION
- ANNEX D: MIM PHY ABSTRACTION
- ANNEX E: EESM GRAPHS
- ANNEX F: ANTENNA PATTERN AND ORIENTATION
- ANNEX G: MODELING PUSC IN SYSTEM SIMULATION
- ANNEX H: A SAMPLE LINK BUDGET ANALYSIS
- ANNEX I: NS2 PROTOCOL LAYER MODULES
- ANNEX J: LIST OF KNOWN SIMULATION MODELS OF WIMAX

Summary



1. System-level ⇒ Multi-cell configuration
2. SLS document provides parameters and methods for simulating various features
3. Covers PHY, MAC and Applications
4. Applies to all simulation tools: NS2, Opnet, Qualnet
5. Applications and MIMO modeling details are original
   ⇒ Now included in 802.16m evaluation methodology

Competing Technologies References

1. **3GPP**, SCM-111, “Spatial Channel Model Text Description”, www.3gpp.org/ftp/tsg_ran/WG1_RL1/3GPP_3GPP2_SCM/ConfCall-16-20030417/SCM-132%20Text%20v5.0.doc
2. **3GPP**, “Spatial channel model for multiple input multiple output (MIMO) simulations,” Release 6, TR25.996 V6.1.0 (2003-09).
3. **3GPP2**, "1xEV-DV Evaluation Methodology," www.3gpp.org/ftp/tsg_ran/tsg_ran/TSGR_AHs/2001_11_3GPP2_HSDPA_Harmonisation/Docs/RPA010006.pdf
4. **3GPP2**, "CDMA2000 Evaluation Methodology," www.3gpp2.org/Public_html/specs/C.R1002-0_v1.0_041221.pdf
5. **WINNER**, "Final Report on Link Level and System Level Channel Models," Nov 2005.
6. **NGMN**, "Next Generation Mobile Networks Radio Access Performance Evaluation Methodology," June 2007, http://www.ngmn.org/docs/NGMN_Evaluation_Methodology_V1.2.pdf
7. **ITU-R** Recommendation M.1225, "Guidelines for evaluation of radio transmission technologies for IMT-2000," 1997